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STATUS OF FUEL UTILISATION FOR INDUSTRY IN JAPAN

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I. INTRODUCTION

1. The amount of energy consumed in Japan 1960 reached $150 \cdot 10^6$ tons in terms of coal equivalent (7000 kcal/kg). This consumption was 1.6 times as much as that in 1955. This increased consumption was caused by a remarkable upswing in industrial production (as indicated by a rise in the index number of mining and manufacturing production to 239 in 1960 from 100 in 1955 base year and also an increased demand for energy for household and commercial uses during the same period.

TABLE 1 Consumption of Primary Energy in Japan

		1955	1960
Hydro-power[a)]	10^6 kwh	48,509	58,474
(Thermal power)[b)]	10^6 kwh	(16,739)	(57,015)
Coal	10^3 tons	47,459	66,138
Lignite	10^3 tons	1,400	1,390
Petroleum	10^3 kℓ	11,945	37,464
Natural gas	10^6 m^3	261	981
Fuelwoods	10^3 m^3	11,700	10,000
Charcoal	10^3 tons	2,089	1,504
Total[c)]	10^3 tons	95,460	154,444

Notes: a) measured at generating points.
b) measured at generating points, and not counted in adding up the total.
c) expressed in terms of coal equivalent (7000 kcal/kg.)

Source: Resources Bureau, Science and Technics Agency.

2. In the midst of changing pattern of energy utilization in Japan, conspicuous was the fact that electric power generation increased by 187% and the petroleum and natural gas came to account for 25.6% of total energy consumption in 1966 as against 17.0% in 1955. Natural gas consumption in Japan was rather little as compared to that in most Western countries.

Coal consumption declined from 44.9% for 1955 to 32.9% for 1960 in relative weight, but rose in the absolute quantity. The rise in coal consumption during the period stemmed mainly from an increased consumption of coking coal. Coal consumed for heating purposes stood stagnant during the period.

Thus, the changing pattern of energy consumption in Japan could be characterised by a tendency towards electrification based on thermal power generation and liquidification in the stage of utilization.

II. CHANGES IN THE AMOUNTS CONSUMED OF ENERGY

3. Changes in the amounts consumed of energy by types of combustion installations used in 1903 major industrial factories between 1955 and 1960 in Japan are shown in Table 2.

TABLE 2 The Amounts Consumed of Energy by Types of Combustion Installations in 1903 Major Industrial Factories in Japan

	Coal 10^3t		Coke 10^3t		Gas 10^6 NM^3		Heavy oil 10^3 kℓ.	
	1955	1960	1955	1960	1955	1960	1955	1960
Water tube boilers	14958	27763	23	14	4878	10606	1006	7047
Other boilers	1651	923	4	8	29	248	291	396
Coke ovens	9707	1060	858	770	3	254	47	363
Gas generators	272	110	32	12	2282	3331	424	1115
Metal heating furnaces	-	91	3872	6386	2840	6735	-	72
Ceramic furnaces	3639	4371	657	188	276	146	275	1056
Shaft furnaces	-	91	3872	6386	2840	6735	-	72
Other furnaces	922	2177	451	1368	2286	6258	1079	1623
Other installations	240	266	92	192	1275	1196	100	207
Total	32209	49279	6095	8993	17965	34689	3224	11888

Notes: 1. The figures refer to 1903 factories.
2. The figures cited here for coal, coke, and heavy oil cover 76%, 75.4%, and 60.8% of the total amount consumed of respective sources of energy.

Source: Technics Promotion Section, National Institute of Industrial Research Ministry of International Trade and Industry.

4. Let us draw some remarks from the Table 2. In 1960, as for coal, water tube boilers used up $25763 \cdot 10^3$ tons, coke ovens $14518 \cdot 10^3$ tons, ceramic furnaces $4371 \cdot 10^3$ tons, and accounted for 52.2%, 29.4%, and 8.8% respectively of total consumption, and also the amount used for each type of these installations was 1.7 times, 1.5 times, and 1.2 times respectively as much as that consumed in 1955. Water tube boilers have been mainly used as giant boilers generating high heat and high pressure for power generation. The use of coke ovens has developed for producing coking coal for iron and steel manufacture, and gas produced as a by-product in the process is to be used in iron and steel mills. Most of ceramic furnaces have been set in cement works.

5. As for coke, shaft furnaces consumed $6386 \cdot 10^3$ tons in 1960 which accounted for 72.6% of the total consumption of it. This was 1.8 times as much in quantity as 1955 level. Besides coke used for shaft and blast furnaces, coke for other uses decreased gradually between 1955 and 1960.

6. Water tube boilers, shaft and blast furnaces, and coke ovens were major demanding parts for gas which corresponded to 57.1% of the total produced in 1960.

7. Among the installations using heavy oil, 1960 water tube boilers consumed $7,047 \cdot 10^3$ kℓ, heating furnaces $1,115 \cdot 10^3$ kℓ, and ceramic furnaces $1,056 \cdot 10^3$ kℓ, so that these three accounted for 77.6% of the total consumption of heavy oil. To 1960 from 1955 the quantity consumed of heavy oil increased to 3.7 times as much as 1955 level and being particularly remarkable the increase of that used in water tube boilers.

III. IMPROVING THE USE OF ENERGY IN SHAFT FURNACES

8. Since coke used for iron manufacture has been more costly in Japan than in most Western countries, many efforts have been made to promote technological advancements in lowering coke ratio in the operation of furnaces, which have contained the promotion of pre-treatment of coking coal, raising the ratio of sinter ore use, improvement of blast furnace to make possible blast with higher heat, adoption of the method of adding vapour to blast, operation of shaft furnace under high pressure, the technique of using blast enriched with oxygen, and the like.

The average ratio of coke per ton of pig iron was 620 kg throughout Japan's iron works in 1960 while it was 720 kg, 1955. The coke ratio will be going down in future.

9. Recently shaft furnaces have become gigantic. So far as iron manufacture relies upon them, however, the extent to which coke ratio is lowered has necessarily a limit. Injecting heavy oil into shaft furnaces has come into picture in order to lower coke ratio while keeping the operating conditions and heat efficiency with shaft furnaces as they were.

Table 3 shows results of heavy oil injection tests performed in Japan. The tests revealed that injecting 70~80 kg of heavy oil per ton of pig iron contributes much to lower coke ratio.

It is considered that further investigations should be made to improve the effect of the oil injecting through facilitating ventilation, gasification of oil, inventing a burner able to perform perfect combustion, standardization of furnace conditions, adjustment in time of injecting, and the like.

TABLE 3 Results of heavy-oil injection tests with B.F. in Japan

	1961 8/27~9/15	1961 9/7 10	1961 9/26 ~ 30	1961 10/26 ~ 31
	Standard Period (no injection)	1st test period	5th test period	11th test period
Oil rate kg/t	-	31.4	75.7	84.4
Output t/d	1,392	1,384	1,416	1,341
Coke ratio kg/t	609	553	484	515
Blast volume Nm^3/Min	1,630	1,610	1,628	1,640
Temperature °C	873	823	882	890
S. R kg/t	359	366	346	380
S %	0.043	0.029	0.060	0.053
CaO/SiO_2	1.16	1.21	1.09	1.18
C.R. decrement/oil rate	-	1.78	1.65	1.11

Notes: (1) Prepared by the Iron and Steel Institute of Japan.
(2) The qualitative characteristics of heavy oil used were as follows:

Carbon	84.75%	Hydrogen	11.15%
Oxygen	0.72%	Nitrogen	0.26%
Sulfur	3.11%		

10. In the field of steel manufacture, recent conspicuous changes are substitution of heavy oil for coal as fuel used in open hearth furnaces and heating furnaces and development of pure oxygen counter over-flow converters.

There existed in Japan thirteen pure oxygen counter over-flow converters amounting to $4843 \cdot 10^3$ tons in capacity at the end of 1960, and six totaling $2430 \cdot 10^3$ tons under construction. The reasons why the converters have developed more rapidly than open hearth furnaces are considered as follows: first, the converters could be constructed at a moderate cost while their capacity to produce is large, second, scrap iron as a material is rather expensive in Japan, third, the cost of operation of converter is cheap because of requiring little fuel.

As fuels for open hearth furnaces and heating furnaces in addition to heavy oil and coal as mentioned above, blast furnace gas and coke oven gas generated in the iron and steel mills are not only in use but, particularly recently, becoming excessive in the light of the balance sheet of gas supplied to iron and steel mills, which are higher at the cost per calory than heavy oil and, therefore, seeking other uses in which they can be utilized more effectively on a sound economic basis.

11. Heavy oil as a fuel for open hearth furnace and heating furnace has many technological advantages over coal (in Japan, coal used in furnaces is called producing-furnace coal), which are as follows:

(a) The cost of construction of oil-using furnaces is lower, the labour force needed to operate it is comparatively fewer, fluctuation in gas contents is slight, and adjustment of burning is easy.

(b) The structure of it could be kept simple.

(c) Heat efficiency reached by using oil is about double as against using coal, and the amount used of vapour is very little.

Thus, although it is evident that heavy oil is advantageous, there are some technological problems around it which are fitness of quality of heavy oil itself, shape and nature of flames, limitation on sulphur content, and inquiry into effects of remaining carbon on working, and the like.

12. At the iron and steel mills in Japan lately, as the volume produced by Bessemer converters and electric arc furnaces rather than open hearth furnaces has markedly been growing, coke oven gas and blast furnace gas have been getting more than enough, which, until recently have been consumed only in the various installations (hot blast stoves, rolling mills, boilers, coke ovens, and open hearth furnaces, etc.), now so that they have come to be supplied to city uses and chemical industry.

As city gas, these kinds of gas are usually sold to the neighbouring city gas distributors from the iron and steel mills. As an input to chemical industry, they are delivered to factories specialized in manufacturing ammonium, which are run either under the complex form of iron and steel company with chemical industry company or under the company subordinate to iron and steel company.

IV. EFFICIENT USE OF FUELS IN BOILERS

13. As shown in Table 2 cited in Clause 3, among various installations using fuels in major factories of Japan, boilers come first in the amount consumed of energy. Furthermore, though not mentioned in the table, there may be a considerable amount of energy consumed by smaller boilers used in small scale enterprises. Among various kinds of energy sources, coal and heavy oil rank highest in caloric terms.

14. The following considerations should be taken into account in order to settle coal and heavy oil respectively in the right place to use them efficiently:

(a) Comparison between both energy sources with respect to their heat efficiency and prices.

(b) Comparison between them with respect to the cost of construction, operation, and maintenance of installations.

(c) Considerations from the viewpoint of environmental sanitation, for example, on air pollution caused especially by smoke.

(d) Considerations on the national interests as to how to maintain national security and pay for so much imported oil which accounts for 98% of total supply to our country, whereas coal is mostly home-produced.

15. Comparing heavy oil with coal as a fuel for boilers, in general the former is better in heat efficiency than the latter.

It goes without saying that it is preferable to apply heavy oil to such types of boiler that makes a big difference in efficiency between heavy oil and coal. For raising heat efficiency of coal, gasification and/or grinding of it is necessary.

A sweeping remark can not be given to the market prices of heavy oil and coal transacted in Japan. Home produced coal can compete with heavy oil in price in such major coal producing regions as Kyushu and Hokkaido, while it is costly as compared with heavy oil and consequently in an unfavourable position, because high cost of transportation must be borne in such major industrial regions more than 500 km distant from coal producing areas as Tokyo, Nagoya, Osaka and so on.

16. Speaking of the cost of constructing installations, small boilers using coal requires less cost than if using heavy oil. Aquisition of coal yards, however, has been getting more difficult in urban areas where land prices are very high. Even in case of coal-using boilers, if the boiler needs pulverized coal, boilers using heavy oil are usually cheaper.

As for the cost of operating and maintaining boilers, heavy oil brings lower costs than coal, thanks to the fact that heavy oil is easier to handle in adjustment of burning has no need to dispose ash, and requires less labour, all of which works in the direction towards lowering the cost. In case of automation of installations, heavy oil is preferable and cheaper.

17. In Japan, May 1962, a law for regulating discharge of smoke was enacted. Facing the fact that heavy oil has perfect combustibility and easiness in handling it, boilers using coal, particularly which are located in urban areas, are in a pressing need of technological improvements. Especially this applies to small boilers below the line of 10 t/h of vapour, while larger boilers achieve better conditions, and leaving no problem with regards to air pollution.

A large amount of heavy oil consumed in Japan is imported from Middle East, which contains comparatively much sulphur. For example, the sulphur content of residual oil after refining crude petroleum from Kuwait is 3.70% in weight. How to prevent bad effects brought by sulphurous acid gas discharged in burning this kind of oil will become a big problem from the viewpoint of environmental sanitation, so that measures for technological betterment are urgently needed.

18. Clauses 14 through 18 are devoted to a general explanation of criteria and their application in settling heavy oil and coal in the right place (except (d) of clause 14 which is irrelevant to this paper). Next we proceed to explain recent developments of the efficient use of energy sources by comparing large scale boilers used for power generation with other boilers.

19. Recent development of power generation in Japan is remarkable. During a five year period ranging from 1956 to 1961, as shown in Table 4, the installed capacity of thermal power generation owned by power companies increased by 233% from $4,367 \cdot 10^3$ kw up to $10,180 \cdot 10^3$ kw, and the amount generated of power increased by 352% from $15442 \cdot 10^6$ kwh to $54384 \cdot 10^6$ kwh.

In line with the increased power production, consumption of energy necessarily increased. During the same five year period, consumption of coal for power

generation showed only an increase of 198% from $8,606 \cdot 10^3$ tons to $17,152 \cdot 10^3$ tons, on the other hand, consumption of heavy oil did a marked increase of 850% from $705 \cdot 10^3$ kilo-liters to $5987 \cdot 10^3$ kilo liters.

TABLE 4 Changes in the capacity of thermal power generation and power production in Japan.

			1956	1961
Installed generating capacity		10^3 kw	4367	10181
kwh generation		10^6 kwh	15442	54384
Consumed amounts	Coal	10^3 t	8606	17152
	Heavy oil	10^3 kℓ	705	5987

Note: Owned by power companies.

Sources: Bureau of Public Utilities, Ministry of International Trade and Industry.

20. As the unit capacity of thermal power generation which has been lately constructed in Japan is very large (The largest $265 \cdot 10^3$ kw among the existing and $375 \cdot 10^3$ kw under construction), boilers attached to power stations become gigantic in their capacity, say in quantitative terms, reaching 908 t/h of vapour, 186 kg/cm^2 of pressure, and 590°C of temperature. Accordingly efficiency attained by these gigantic boilers is very high irrespective of differences in quality of energy obtained between heavy oil and coal. Taking as an example a thermal power station located in Tokyo, efficiency of its boiler is 93.5% when burning coal and 95.0% when using oil.

The reasons for a marked increase in consumption of heavy oil as mentioned in Clause 19 are not only attributed to higher efficiency of boilers through using it but also cheapness in the price of it and the cost of fixed capital as compared with using coal. While the price of coal slightly decreased from 23 mils per 1,000 kcal to 2.03 mils between 1956 and 1960, the price of heavy oil sharply decreased from 3.42 mils to 1.83 mils in the same period. At present, this difference in price is very big particularly in such major industrial regions as Tokyo, Osaka, and Nagoya where power generation is tremendous, and consequently heavy oil is getting a more advantageous position.

Power industry is one of the representatives of apparatus industry in Japan. Rapid development of capacity to generate power requires a tremendous amount of capital to invest. This applies to thermal power stations too. While the investment cost per kw in case of constructing installation using coal is estimated at about 180 dollars, the cost in case of heavy oil is less than 130 dollars. So it is no wonder if construction of thermal power station relying oil only is preferred owing to saving of more than 50 dollars per kw.

21. Speaking of boilers other than used for power generation, water tube boilers with bigger capacity of 10 t/h of vapour produced efficiently work irrespective of using coal or heavy oil. But other types of boilers are not so good in their efficiency. As shown in Table 5, the other types of boilers surpass water tube boilers in number of installation, which are in capacity below one t/h.

Appraising highly practices such as mechanization of burning operation, attaching economizers and replacing boilers with low load, which we hear are followed in England, similar measures are under consideration and partly under way.

Measures and practices to be taken in Japan are as follows:

(a) Promotion of modernization including automation, and replacement, intensive use, and expansion of size of installations.

(b) Research and development of small scale boilers with high efficiency.

(c) Strengthening of technological guidance activities.

(d) Financial arrangements favourable for replacement and improvement of installations.

TABLE 5 Installed number of boilers by type in Japan

	1957	1959	1961
Water tube	3432	3890	4867
Lancashire	1680	1515	1367
Cornish	5204	4816	4629
Vertical	13801	15225	15494
Horizontal smoke tube	15208	16568	18360
Others	10993	11744	14819
Total	50318	53758	59532

Note: Excluding boilers used in locomotives and ships.

Source: Ministry of Labour

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